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Power system protection and automation reference

Extending substation life cycle with IEC 61850

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A step-by-step power system retrofit approach for optimizing substation investment costs

Vaasan Sähköverkko Oy, a subsidiary of Vaasan Sähkö Oy, is a power transmission and distribution company in western Finland. Facing an aging protection relay base Vaasan Sähköverkko Oy has made a strategic decision to adopt the IEC 61850 standard in all new and retrofit substation automation projects to meet the requirements of future power systems. By implementing a step-by-step approach in retrofit projects the substation automation equipment will be renewed. This will extend the operational life cycle of the original MEKA 24 switchgear system delivered by Strömberg (now merged with ABB) in the 80's, thus minimizing the investment costs while increasing network reliability.

The Vörå 110/20 kV substation is located in a rural area with over 1700 end customers, consisting of private homes, farmers, manufacturing industry and the city of the Vörå-Maxmo municipality. The substation supplies electricity to a 150 km² wide area, mainly through over-head line feeders. The ratio of cable feeders to overhead line feeders in the supply area is quite low, less than 10% of the total network length, compared to other distribution areas of Vaasan Sähköverkko Oy. The Vörå substation features a double busbar system with a main busbar for normal operation and an auxiliary busbar mainly used during substation maintenance. In addition, a backup generator, rated for the full load of the four feeders, can be thrown in to secure power if the incoming power supply is interrupted.

A step-by-step retrofit approach

The protection and control equipment in the substation included SPAJ 3A5 J3 overcurrent relays and SPAA 3A5 J40 feeder terminals representing static relay technology from the 80's. In the retrofit project the old relays and terminals were replaced with new Relion® 630 series IEDs (intelligent electronic device) of native IEC 61850 design paving way for the next steps of the step-by-step substation retrofit project. Vaasan Sähköverkko Oy has initiated an investment program allocating network investments over several upgrade steps. The company aims at utilizing the whole design life cycle of both substation devices and other network components. "Automation has proven to be a good approach to extend the life cycle of substations and switchgear systems. The substations themselves may be aged, but by means of automation we are able to unify their operating manners and maintenance procedures to extend their life cycles," says **Juha Rintamäki**, CEO of Vaasan Sähköverkko Oy. To further take advantage of the modern IEDs, the station automation device COM600 will be used to connect the IEDs to the network control centre using the IEC 104 protocol. The communication network (LAN) of the substation has already been installed to allow for the next steps of the retrofit project.

Committed to the IEC 61850 standard

Vaasan Sähköverkko Oy has made a strategic decision to adopt the IEC 61850 standard in all new and retrofit substation automation projects. The first IEC 61850 compliant substation retrofit project was finalized in 2006 and the project has been followed by both new substation

The first step of the retrofit project was finalized in early 2010.





Juha Rintamäki, CEO of Vaasan Sähköverkko Oy.

projects and retrofit projects. "Every new substation we build and every switchgear panel we retrofit will be geared up for IEC 61850. This means that when old substations are modernized and the protection system is exchanged we regularly choose IEC 61850 compliant protection devices or at least it must be possible to convert information into IEC 61850 format," says Juha Rintamäki.

By implementing the IEC 61850 standard on the Vöörå substation, comprehensive substation data can be transferred to the network control centre (NCC) and the substation remote control interfaces at the network control centre (NCC) can gradually be harmonized. "The IEC 61850 station bus enables substations to be mutually unified. At the same time a unified image of the substations is created for the distribution management, i.e. a unified interface and functions of a similar kind. In this way it is easier to manage the network as an entity," Juha Rintamäki claims. "One eminent feature of the IEC 61850 standard is that it is vendor independent. This is a security factor from the network operator's point of view. The standard is also a pathway to the future. It may be on hand for a long time still. It is constantly being developed and maintained according to the requests of power system operators," continues Juha Rintamäki.

Increased functionality – a major leap reflecting the relay development over the last 25 years

In the retrofit project the old J-series protection relays were replaced with nine feeder protection and control IEDs type REF630, and one RET630 transformer protection and control IED. By renewing the old relay stock major improvements were achieved within the field of protection, measurement and supervision of the substation. "New technology is introduced in stead of the aging technology in those devices, which are near the end of their effective life time. With the renewal of the equipment we aim at improving the operational reliability of the network. The immediate benefit of a renewal of the equipment on the switchgear cubicle level is that the protection relays make available more selective and better protection functions. Furthermore, the new devices offer protection functions previously not presented in protection relays. I would like to particularly point at the functionality of the new relays, such as the fault location function and the fault event recorder function. These functions were typically not included in older relay generations," Juha Rintamäki tells.

The 630 series IEDs include more functionality and protection stages than the old J-series relays. The use of multiple stage overcurrent relays speeds up protection operating times and enable settings to be completely defined on the basis of the requirements of the protected object. When analog relays (SPAJ 3A5 J3, SPAA 3A5 J40) are used the grading time between successive protection stages is 300 ms. With modern state-of-the art relays the grading time can be as short as 150 ms, providing faster protection while still maintaining selectivity.

Even the earth-fault protection scheme can be based on multiple protection stages, which makes it easier to match the protection to the safety regulations. At the same time intermittent earth faults can be granted time to self-extinguish thus avoiding unnecessary auto-reclosing.

Indication of intermittent earth faults is a new protection function, which is especially useful for protection of cable sections in the network. Cable faults typically start with stochastically appearing faults, which disappear by themselves. This phenomenon, however, makes the network to oscillate relatively to earth, which in turn may trigger the busbar residual voltage protection. By means of the earth-fault indication the faulty cable section can be reliably

identified and a trip command to the circuit breaker of the concerned cable can be issued in the proper stage of the fault development. A drawback of traditional protection systems is that they reset between faults, thus delaying the operation of the protection, and which may cause unnecessary operation of the busbar residual voltage protection. Furthermore, due to the multiple stage residual voltage relay it is possible to freely choose setting values for the non-tripping residual voltage stage supervising the network and the tripping stage providing backup earth-fault protection.

The starting and operating sequences of the auto-reclose functions have very versatile settings. The selections can be made separately for each protection function, thus avoiding unnecessary auto-reclosing, for example at three-phase close-up faults or in earth-fault situation caused by a broken phase conductor.

The condition monitoring functionality of the installed 630 series IEDs continuously monitors and stores information about the condition of the circuit breakers. The monitoring functions provide operational circuit breaker (CB) history data, which can be used for scheduling preventive CB maintenance, contributing to improved asset management of the primary apparatuses. In addition, the new 630 series IEDs offer completely new means for recording information in network disturbance situations. The disturbance recorder and event log data is stored in a non-volatile memory and is thereby also maintained, should the IEDs suffer an interruption of the power supply. The comprehensive disturbance records can be viewed locally at the substation or downloaded for in-depth analysis. By analyzing the recorded data valuable network disturbance information is gained enabling Vaasan Sähköverkko Oy to even further fine-tune the parameter settings and improve the reliability of the equipment during network disturbance situations. "Previously there was no way to obtain fault location information to be transferred to the SCADA/DMS system. And we had no detailed interference records from appearing faults to be used for post-fault analysis and evaluation of possible fault reasons. These are immediate benefits which we aim at by investing in new protection equipment," says Juha Rintamäki.

The transition from the protection technology of the 80's to modern IEC 61850 compliant IEDs also requires hands-on training and clear operation instructions. To support the

commissioning phase of the substation ABB offered Vaasan Sähköverkko Oy on-site training and created a quick reference guide illustrating the main menus and features of the local human-machine interface (HMI). The reference guide has made the hands-on operation of the IEDs easier contributing to efficient local operation of the IEDs at the substation.

Reliable operation during heavy thunderstorms over western Finland

The updated Vörå substation was officially taken into use in January 2010. The first months of operation at the Vörå substation has put the 630 IEDs to the test. With up to 15 km lines per main feeder and up to 30 km of branch lines per overhead line feeder, the network and the protection devices were put to the test during heavy thunderstorms over western Finland. No permanent network faults were registered by the IEDs during the first six months of operation. The patented operating sequence of the auto-reclose function in the 630 series IEDs enabled all transient and semi-transient faults to be cleared, and a fast restoration of the electricity supply.





The 630 series IEDs and REA arc protection system were installed in the MEKA 24 switchgear.

Personnel safety plays a key role for Vaasan Sähköverkko Oy

In addition to the renewal of the J-series relays Vaasan Sähköverkko Oy decided to install ABB's REA 101 arc protection system and two REA 107 extension units. An arc fault in the switchgear may, in the worst case, result in loss of human lives and/or cause a need for a total exchange of the switchgear. Arcs in the switchgear are usually difficult to foresee as they, in most situations, are caused by human errors during, for example, maintenance work. However, by applying an arc protection scheme both the risk for loss of human lives and material damage in the switchgear is reduced. Further, by limiting material damage of the switchgear in a fault situation, the downtime can be reduced. "Obviously, one of the main investment drivers is personal safety. Secondly, if an arc fault is left raging for too long a time, it will cause a long interruption of the supply of power and high repair costs. This is naturally also an important investment reasoning," Juha Rintamäki considers.

In the Vörå substation lens type arc detection sensors are used. Two sensors are installed in the busbar compartment of the incoming feeder cubicle. In addition, each outgoing feeder bay is equipped with one sensor. By complementing the protection functions of the 630 series IEDs with the REA arc protection system a prolonged use of the switchgear is supported.

Investing in the distribution network and substation automation is a continuous process

Managing the power distribution network and the related assets constitute the foundation of the business of Vaasan Sähköverkko Oy. It is thereby self-evident that power system components and automation products will have to be replaced from time to time to ensure reliable operation.

After a successful renewal of the protection relays in the Vörå substation, the subsequent measure includes installation and commissioning of ABB's Station Automation device COM600. This will allow the outdated modem based control system to be replaced with new technology. In due time the switchgear system will also have to be renewed or thoroughly overhauled including exchange of the circuit breakers.

As the power demand in the region is steadily growing, Vaasan Sähköverkko Oy finds it natural to do investments, as the company, at the same time, adds power distribution capacity to satisfy the actual customer demand. "We can build new networks and update existing ones alike, replacing old equipment with modern components. What we have here is a process of continuous development," Juha Rintamäki concludes.

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